Renewable and Sustainable Energy Reviews 16 (2012) 3967–3974

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative

Musiliu O. Oseni*

Economics Department, Al-Hikmah University Ilorin, P.M.B. 1601, Ilorin, Nigeria

ARTICLE INFO

Article history:
Received 24 August 2011
Accepted 5 March 2012
Available online 28 April 2012

Keywords:
Energy consumption
Electricity access
Renewable energy
Hydro
Wind
Solar

ABSTRACT

Access to substantial quantity and quality energy infrastructures is essential to rapid and sustainable economic development. Access to modern energy services directly contributes to economic growth and poverty reduction through the creation of wealth. No country can develop and sustain beyond subsistence means without having at least minimum access to energy services for the larger portion of its population. The present study examines the households' access to modern energy (electricity) services and pattern of energy consumption in Nigeria. It was found that the access to modern form of energy in the country is very low despite the country's abundant energy endowment. Greater proportions (over 40%) of Nigerian households do not have access to electricity and still depend largely on traditional forms of energy (e.g., firewood, kerosene, etc.) as energy sources. However, Nigeria is abundantly endowed with renewable energy resources. This can be significantly developed to generate modern and clean electricity to meet the yearning demand of its citizens without imposing serious hazard on the environment.

Contents

1. Introduction

Substantial expansion in quantity, quality, and access to energy infrastructure services are essential to rapid and sustained economic growth, employment generation, poverty reduction and overall wellbeing of a country where greater portion of its population resides in the rural areas. Continuous access to quality energy infrastructure is an essential ingredient for sustained economic growth and development. Energy is a vital ingredient for development and a powerful engine of social and economic change in that no country can manage to develop and sustain beyond a subsistence economy without having at least minimum access to energy services for the larger portion of its population [1]. Studies have shown a strong correlation between energy consumption and economic growth; access to modern energy (electricity) services directly contributes to economic growth and poverty reduction through the creation of wealth. China for example has moved 300 millions of her citizens out of poverty since 1990 through increased access to energy [2]. One major driver of energy demand is population, its rapid increase coupled with industrialisation in the 20th century have brought about a huge energy demand [3,4]. Energy infrastructure serves as an essential input into private sector production, thus augments output and productivity [5]. However, lack of access to energy infrastructure seriously hinders economic growth,

* Tel.: +234 8067618670.
E-mail address: musloseni@yahoo.com

1364-0321/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.rser.2012.03.010

Table 1
Nigeria energy reserves/capacity as at December 2005.

Energy source	Reserves
Crude oil	36.5 billion barrels
Natural gas	187.44 TCF
Tar sands	30 billion barrels of oil equivalent
Coal and lignite	Over 40 billion tonnes
Large hydropower	11,235 MW
Small hydropower	3500 MW
Fuel wood	13,071,464 ha
Animal wastes	61 million tonnes/yr
Crop residue	83 million tonnes/yr
Solar radiation	3.5–7.5 kWh/m^2 day
Wind	2–4 m/s at 10 m height

Source: Draft National Energy Master plan, Energy Commission of Nigeria, June 2007.

undermines employment and consequently results in a vicious circle of poverty.

Nigeria is endowed with abundant natural energy resources including crude oil, natural gas, coal and lignite, hydropower, solar radiation, wind, biomass (fuel-wood, animal and plant wastes), nuclear among others. It is one of the top crude oil exporters in the world and has the 7th largest natural gas reserve in the world and second in Africa after Libya.[1] However, some of these resources are yet to be tapped while the maximum utilisation of others is not in view, thus making energy a major concern and priority in the country. Hence, rapid growth in the energy need above generation levels and poor access have therefore always been the result of resources underutilisation and a major constraint to economic growth.

Energy potential is vital to economic growth, but access and utilisation is an engine and driver of growth and development. Thus, a good understanding of energy potential, access and utilisation becomes very necessary given its importance to future energy planning and rapid economic development of a country. This paper therefore examines the level of households' access to energy across the Nigerian states and offers some policy guidelines for improved energy production, access and utilisation in the country. The study is structured as follows. The next section discusses the indicators of Nigerian economy and energy sector. Section 3 present the overview of electricity generation and distribution in the country. The following section concentrates on access to electricity and energy consumption pattern, Section 5 examines the country's renewable energy potential for improving energy access while the last section concludes with policy recommendations.

2. Key performance indicators of Nigerian economy and energy sector

The Federal Republic of Nigeria, located between longitude 3° E and 14° E in the Western part of Africa, has an area of about 923,768 sq. km and a population of over 150 million residing in its 36 states and the Federal Capital Territory [6]. Table 1 presents the Nigeria's energy potential as at 2005 [7]. It is clearly shown that Nigeria is rich in both fossil fuels and renewable energy. The proven reserve of crude oil is over 36 billion barrels, natural gas (187.44 tcf), while tar sands and coal and lignite are 30 billion of oil equivalent and over 40 billion tonnes respectively. The small and large hydropower potential of Nigeria stand at 3500 MW and 11,235 MW, while fuel wood, animal wastes and crop residue are respectively 13,071,464 ha, 61 million tonnes/year and 83 million tonnes/year. The location of the country also favours solar and wind energy sources. With solar radiation of 3.5–7.5 kWh/m^2 day and wind speed of 2–4 m/s at 10 m height, these are respectively one of the greatest experiences in the world.

With its fast growing population, energy need per person, poor technology and fast growing urbanisation, Nigeria has been one of the countries with fast growing modern energy (electricity) needs in the world over the last two decades. Nigeria is a major producer of primary energy but greater percentage of her secondary energy is supplied by imports [8], mainly due to inadequate technology to transform the country's primary energy from its raw state into usable form. In 2007, indigenous primary energy production has reached 230.24 million tonnes of oil equivalent (Mtoe). This was largely dominated by crude oil production which accounts for approximately 50% of the total production. However, Nigeria consumed 8.41 million tonnes of oil equivalent of petroleum products in 2007 with more than 93% of it imported. An analysis of the Nigerian energy balance presented in Table 2 also indicates that fossil fuels provided about 61.4% of the total indigenous primary energy production, with crude oil (49.9%) and natural gas (11.5%). Contrary to its contribution to the indigenous production, fossil fuels have only contributed 17.8% to the total primary energy consumption in the country. This is not surprising because the greater portion of the crude oil produced in the country is usually exported. In 2007, more than 98% of the crude oil extracted in the country was exported, leaving less than 2% for local consumption. The renewables collectively account for about 49% of indigenous energy production and contributes 82.2% to primary energy demand in the same year. This was mostly in the form of combustible renewable and wastes (81.7%) – mostly fuelwood – and hydropower (0.5%).[2] Nigeria's total electricity production was 22,978 GWh (2623 MW). The distribution of the produced electricity energy output according to primary energy sources was as follows: oil, i.e., petroleum products (21.4%), natural gas (51.5%), and hydropower (27.1%). Table 2 reflects the increasing reliance on natural gas in the power sector. It had the largest share in gross electricity output in 2007.[3] This represents an increase of 16.3% over its 2006 contribution to the country's gross electricity generation.

Nigeria's dynamic economy is a complex mix of modern industries and commerce along with a traditional agricultural sector that still accounts for more than 60% of employment generation and highest contribution to the gross domestic products (GDP) in the country. It has a strong and rapidly growing private sector, yet the state still plays a major role in the power industry. Real GDP growth has exceeded 5% in many years, but this strong expansion has been interrupted by sharp declines in output in 1978, 1981, 1983 and 1984. The economy is turning around with the implementation of economic reforms, and 2004 GDP growth reached 10%, followed by roughly 6% annual growth from 2005 to 2008. The GDP per capita is currently over 480 US$ 2000 constant and grows at approximately 6% per annum [9]. The manufacturing utilisation rates rose from 76.6% in 1975 to a peak of 78.7% in 1978 before maintaining a sharp decline to 38.8% in 1986. It however continues to rise up to 43.8% in 1989. It subsequently maintains a downward movement until 2002 and is currently barely above 53% [10]. It is important to note that the movement of capacity utilisation in the country has been driven by major economic reforms, Operation Feed the Nation (1976–1978), Structural Adjustment Programme (1986–1989), and the ongoing National Economic Empowerment and Development

[1] Nigeria's natural gas reserve currently stands at 188 trillion cubic feet (Tcf).

[2] This shows the impacts of the increasing level of awareness of the Nigerian government about the country's renewable energy potential and the need for its utilisation in order to meet the yearning demand for energy by the citizens. However, renewable energy (except large hydro) utilisation for modern energy generation is still very low.

[3] Nigeria is the seventh largest natural gas producer in the world and the second largest gas flarer. Arguably, Nigeria can further increase the natural gas share in electric power production by reducing its gas flaring.

Table 2
Consolidated Nigerian energy balance 2007.

Energy supplied basis: thousand tonnes of oil equivalent								
Source	Primary fuel availability Coal and manufactured fuels	Oil and petroleum products	Natural gas	Hydro	Renewable and waste	Electricity	Heat	Total
1 Indigenous production	4.93	114,850.66	26,540.15	535.52	88,309.41	0.00	0.00	230,240.7
2 Imports	0.00	7877.13	0.00	0.00	0.00	0.00	0.00	7877.126
3 Exports	0.00	−114,543.47	−17,743.80	0.00	0.00	0.00	0.00	−132,287
4 Marine bunkers	0.00	−1070.05	0.00	0.00	0.00	0.00	0.00	−1070.05
5 Stock changes	0.00	560.74	0.00	0.00	0.00	0.00	0.00	560.744
6 Primary energy supply	4.93	7675.01	8796.35	535.52	88,309.41	0.00	0.00	105,321.2
7 Statistical differences	0.00	2466.56	329.08	0.00	−0.05	0.00	0.00	2795.591
8 Primary demand	4.93	10,141.57	9125.43	535.52	88,309.36	0.00	0.00	108,116.8
9 Transfers and transformation	0.00	−1450.87	−2615.14	−535.52	−2347.05	1976.11	0.00	−4972.47
10 Energy industry use	0.00	−249.04	−4118.95	0.00	0.00	−56.50	0.00	−4424.48
11 Distribution losses	0.00	−28.72	−910.90	0.00	0.00	−227.90	0.00	−1167.52
12 Final consumption	4.93	8412.95	1480.45	0.00	85,962.31	1691.71	0.00	97,552.34
13 Non-energy use	0.00	122.60	0.00	0.00	0.00	0.00		122.599
14 Final energy consumption Source	4.93	8290.35	1480.45	0.00	85,962.31	1691.71	0.00	97,429.74
14a Industry	4.93	156.37	1480.45	0.00	8700.56	372.21	0.00	10,714.51
14b Transport	0.00	7697.49	0.00	0.00	0.00	0.00	0.00	7697.488
14c Domestic	0.00	436.49	0.00	0.00	77,261.76	867.83	0.00	78,566.07
14d Commercial and public services	0.00	0.00	0.00	0.00	0.00	451.67	0.00	451.672
Electricity output in GWh	0.00	4919.00	11,832.00	6227.00	0.00	0.00	0.00	22,978
Elect output-main act. producer electricity plants	0.00	4919.00	11,832.00	6100.00	0.00	0.00	0.00	22,851
Electricity output-autoproducer electricity plants	0.00	0.00	0.00	127.00	0.00	0.00	0.00	127

Data source: World Energy Balances of Countries, IEA (Edition: 2010).

Table 3
Selected indicators for Nigeria.

Indicator	Value
Population (million)	151,319,499 (2008 est.)
Population growth rate	2.3% (2008 est.)
GDP (Nominal in naira)	29, 398 billion (2009 est.)
GDP (US $ current prices)	202.16 billion (2009 est.)
RGDP growth	5.8% (2009 est.)
GDP per capita (US $ current)	1557 (2009 est.)
Investment % of GDP	25.8% (2009 est.)
CPI	5.5% (2007 est.)
Electricity Consp. per capita	137.19 (2007 est.)
Manufacturing capacity utilisation rate	53.38 (2007 est.)

Strategy (NEEDs) which commenced in 2001. However, this low utilisation rates, compared to other countries of the world, might not be unconnected with the acute shortage of electricity in the country. In 2005, MAN declared that the shortage of electricity supply is a major constraint to the manufacturing sector in Nigeria and is responsible for the uncompetitive nature of the goods produced in the country [7].[4] Inflation rate has fallen drastically from its two digits value to a single digit value of 5.3% in 2007. In short, the Nigerian economy is fundamentally strong as depicted by the macro-economic indicators presented in Table 3.

Nigeria's population of more than 150 million is growing at an annual rate of 2.03% and expected to grow to over 180 million in 2020 [11]. In response to the growth rates of population and consumption, Nigeria's total final energy consumption (TFC) grew at an average annual rate of 3.9% over the last three decades. This average annual growth rate of TFC is projected to grow between 11.5% and 13% in the next two decades [11].

[4] MAN is an acronym for 'Manufacturers Association of Nigeria'.

3. Electricity generation and distribution in Nigeria

Table 4 presents the country's gross electricity output generated from 2007 to 2008 by stations. Energy generated in 2007 and 2008 amounted to 22,978,128.66 MWh and 20,980,778.96 MWh respectively. 2008 shows a drop of 1,997,349.7 over 2007 generation. This decline in generation might be connected with the inability of the government to adequately fund the sector due to fall in revenue resulted from the global economic crisis of late 2007. In the years of reference, Egbin power station recorded the highest contribution to the total electricity output with 23% and 21% respectively for 2007 and 2008 while Rivers and NESCO power plants recorded the lowest output for 2007 and 2008 respectively.

The distribution of electric energy presented in Table 5 shows a decrease of 4.49% in energy distributed in 2008 as against the distribution in 2007. This was largely due to, apart from low generation, high distribution losses recorded in the country in 2008

Table 4
Generation of energy in MWh by power stations.

Station	2007	% of total	2008	% of total
Kainji	2,816,749.70	12.26	2,707,020.00	12.90
Jebba	2,750,325.00	11.97	2,794,976.00	13.32
Shiroro	2,230,768.00	9.71	2,089,460.00	9.96
Egbin	3,636,680.52	15.83	4,528,451.09	21.58
AES	1,552,586.28	6.76	1,846,704.40	8.80
Omotosho	147,541.06	0.64	491,324.90	2.34
Afam	1,401,159.60	6.10	300,209.60	1.43
Okpai	3,294,207.00	14.34	2,708,690.80	12.91
Sapele	490,290	2.13	728,977.00	3.47
Delta	2,696,718.60	11.74	1,510,988.00	7.20
Ajaokuta	357,110.00	1.55	995,873.98	4.75
Geregu	1,208,341.20	5.26	na	na
Omoku	348,583.54	1.52	211,752.37	1.01
Rivers	9976.00	0.04	42,960.00	0.20
NESCO	37,092.16	0.16	23,390.82	0.11
Total	22,978,128.66	100.00	20,980,778.96	100.00

Table 5
Distribution of energy in MWh by power stations.

Station	2006	% of total	2007	% of total	2008	% of total
Kainji	2,354,982.03	10.27	2,809,551.13	12.71	2,668,862.67	13.92
Jebba	2,138,780.00	9.33	2,698,296.20	12.21	2,756,929.64	14.38
Shiroro	2,420,330.30	10.56	2,217,890.10	10.03	1,913,856.70	9.98
Egbin	4,977,217.00	21.71	3,692,918.00	16.71	4,610,755.90	24.05
AES	1,916,443.65	8.36	1,585,690.00	7.17	1,674,955.60	8.73
Omotosho	0	0.00	110,871.32	0.50	0	0.00
Afam	1,711,346.60	7.47	1,187,875.00	5.37	397,214.00	2.07
Okpai	3,207,835.30	13.99	3,223,565.04	14.58	2,688,376.40	14.02
Sapele	171,120.00	0.75	447,825.00	2.03	716,616.00	3.74
Delta	3,662,597.77	15.98	2,564,509.44	11.60	1,476,291.93	7.70
Ajaokuta	218,039.00	0.95	232,264.00	1.05	7904.00	0.04
Geregu		0.00	1,010,498.12	4.57		0.00
Omoku	na		299,977.02	1.36	197,291.00	1.03
Rivers	110,272.00	0.48	10,346.00	0.05	41,118.75	0.21
NESCO	35,056.77	0.15	36,959.90	0.17	25,232.07	0.13
Total	22,924,020.42	100.00	22,104,559.15	100.00	19,175,404.66	100.00

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.

Table 6
Annual energy delivered to the zones/districts from the grid.

Zone	2007	% of total	2008	% of total
Abuja	2,186,139,840	10.57	1,799,314,307.00	5.71
Benin	2,193,220,720	10.60	1,918,939,346.00	6.09
Eko	2,678,230,850	12.94	1,766,529,137.00	5.61
Enugu	2,033,032,910	9.83	1,729,306,451.16	5.49
Ibadan	2,578,055,850	12.46	2,075,120,186.00	6.58
Ikeja	3,350,335,060	16.19	2,475,190,392.98	7.85
Jos	977,813,620	4.73	721,505,874.00	2.29
Kaduna	1,649,559,920	7.97	1,002,824,801.00	3.18
Kano	1,155,764,970	5.59	908,811,802.30	2.88
Port Harcourt	1,126,046,100	5.44	1,004,123,622.06	3.19
Yola	382,936,680	1.85	356,730,486.20	1.13
Nigelec	380,539,000	1.84	15,758,396,405.70	50.00
Total	20,691,675,520	100.00	31,516,792,811.40	100.00

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.

compared to 2007.[5] This high loss ratio possibly reflects the obsolete nature of the country's electricity distribution equipments. Egbin power station contributed the highest with 21.84% of the total energy (electricity) distributed in 2008 while Jebba and Okpai stations had 13.06% and 12.73% respectively. The least of energy distributed came from Ajaokuta station with 0.04%.

Annual energy (electricity) delivered to different zones or grids across the countries shows an improvement of 52.32% in 2008 over the 2007 record. Ikeja zone received the highest delivery in 2007 with 16.19% of the total, followed by Eko zone with 12.94%. The NIGELEC zone recorded the lowest delivery with 1.84% (Table 6). But the 2008 record was a complete reversal of the lowest in 2007 as it had the highest in 2008, dominating with 50.00% of the total. It was however followed by Ikeja and Ibadan zones with 7.85% and 6.58% respectively. Yola zone recorded the lowest with 1.13%.

In another development, the total electricity delivered to DISCOS in 2007 amounted to 19,670,622.59 MWh as recorded in Table 7. It however dropped by 6.20% in 2008, where Ikeja DISCOS accounted for the highest with 14.35% of the total. Ibadan and Abuja DISCOS followed with 11.73% and 11.18% respectively, while Itakpe recorded the least with just 0.01%.

4. Access to electricity and energy consumption pattern

Household access to electricity services in Nigeria is low. About 60% of the population – over 80 million people are not served with electricity and rural and semi-urban access to electricity estimated to be about 35%. Per capita consumption of electricity is approximately 125 kWh against 4500 kWh, 1934 kWh and 1379 kWh in South Africa, Brazil and China respectively [7]. Table 8 shows the percentage distribution of households by source of electricity consumed in 2007 and 2008 across the 36 states (including FCT) of the federation. Energy supply forms the bed rock of economic development. Over the years, more than 40.0% of the households did not have access to electricity in the country, 41.4% in 2007 and 48.0% in 2008. This continuous rise in households without access may be connected with rising rates of population growth without corresponding improvements in electricity supply. In 2007, only about 47.3% of the households had access to electricity from Power Holding Company of Nigeria (PHCN), and this figure decreased to 40.4% in 2008. It was observed that Taraba State recorded the highest percentage of households without electricity in 2008, about 88.8%, while Lagos with 0.3% recorded the least. Conversely, Ogun State had the highest percentage of households using PHCN with 69.8%, while Taraba State had the least with 2.8%. The households depending on self-diesel generating plants rose from 2.7% to 3.2% over the period. Similarly, households complementing power form the national grid with diesel generating plants also rose to 6.3% in 2008 from 5.8% in 2007. It is clearly shown that the rural electrification programme in the country is yet to record a remarkable progress with just 0.9% of household being its beneficiary. Solar energy is yet to be substantially utilised despite the country's solar potential while nuclear energy is still not in use at all.

Table 7
Annual energy delivered in MWh to the DISCOS.

Discos	2007	% of total	2008	% of total
Abuja	2,046,158.75	10.40	2,062,328.62	11.18
Benin	2,123,766.27	10.80	2,054,046.90	11.13
Eko	2,117,656.80	10.77	1,763,833.83	9.56
Enugu	1,931,482.53	9.82	1,816,756.21	9.85
Ibadan	2,271,074.42	11.55	2,164,011.78	11.73
Ikeja	2,835,480.95	14.41	2,648,712.20	14.35
Jos	976,667.61	4.97	835,470.28	4.53
Kaduna	1,650,280.73	8.39	1,417,426.26	7.68
Kano	1,002,650.29	5.10	1,065,186.16	5.77
Port Harcourt	972,530.53	4.94	908,225.93	4.92
Yola	423,504.31	2.15	375,132.80	2.03
Ajaokuta	7613.00	0.04	58,404.00	0.31
Ceb (Sakete)	570,151.00	2.90	641,280.00	3.48
Delta steel	274,261.80	1.39	170,903.66	0.93
Nigelec	449,300.40	2.28	467,542.60	2.53
Itakpe	18,043.20	0.09	2314.89	0.01
Total	19,670,622.59	100	18,451,576.12	100

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.

5 Nigeria recorded a distribution loss of 8.6% in 2008 as against 3.8% in 2007.

Table 8
Percentage distribution of households by state and electricity supply, 2007 and 2008.

State	PHCN Only	Rural electrification only	Private generator only	PHCN/Generator	Rural electrification/Generator	Solar energy	None
Abia	44.5 [45.7]	0.1 [1.3]	5.9 [6.5]	15.2 [13.5]	0.5 [1.8]	0 [0]	33.8 [31.1]
Adamawa	22.3 [22.6]	0 [0]	1 [3.4]	4.9 [3.9]	0.5 [0.4]	0 [0]	71.4 [69.8]
Akwa Ibom	46.3 [40.6]	2.7 [1.7]	3.3 [7.9]	7.6 [5.9]	1.9 [0.2]	0 [0.2]	38.3 [44.6]
Anambra	58 [61.9]	4.1 [0]	0.2 [3]	6.8 [7.9]	0 [2.3]	0 [0]	30.9 [24.4]
Bauchi	38.7 [31.4]	0 [5.3]	0 [0]	2.8 [3.2]	0 [0]	0 [0]	58.5 [60.2]
Bayelsa	10.3 [21.6]	10.1 [23.3]	13.3 [8.6]	5.8 [7.5]	37.8 [12.2]	0.5 [0]	22.2 [36.9]
Benue	15.7 [22.8]	0 [0]	2.8 [4.2]	2.5 [0.9]	0.5 [0.2]	0 [0]	78.6 [72]
Borno	19.4 [15.2]	4.6 [0]	10.6 [3.8]	0.9 [3.6]	0.1 [0]	0 [0.2]	64.5 [77.3]
C/River	54.1 [40.6]	0.5 [0.3]	3.2 [3.4]	1.7 [9]	3.4 [0.3]	0 [0]	37.1 [46.3]
Delta	62.7 [56.8]	0 [0]	2.5 [2.9]	3 [7.5]	1.6 [3.1]	0 [0]	30.2 [29.6]
Ebonyi	14.7 [12.3]	5 [8.3]	5 [3.2]	0.3 [2.5]	1.5 [5.6]	0 [0]	73.5 [68.1]
Edo	80.7 [77.7]	0 [1.9]	1.5 [2]	0.9 [3.2]	0 [0]	0.1 [0]	16.9 [15.2]
Ekiti	56.7 [61]	0 [0]	1.2 [1.6]	0.8 [5.2]	0 [0.2]	0 [0]	41.3 [32.1]
Enugu	45.6 [44.9]	0.2 [0.5]	3.6 [3.6]	5.5 [4.8]	0.3 [0.3]	0 [0]	44.8 [45.8]
Gombe	50.7 [39.5]	0 [0.9]	0 [0.9]	0 [3.4]	0 [0]	0[0]	49.3 [55.4]
Imo	68.5 [69.5]	1.4 [0.3]	5.2 [4.6]	4.1 [12.8]	0.1[0.2]	0 [0]	20.8 [12.6]
Jigawa	39.4 [41.6]	0 [0.2]	0.2 [0.2]	0.4 [1.4]	0 [0.2]	0 [0]	60 [56.5]
Kaduna	53.5 [46.2]	0.5 [0.2]	1.2 [1.8]	2.9 [8.2]	0.2 [1.2]	0 [0]	41.8 [42.4]
Kano	59.6 [42.6]	0 [0]	0 [0.3]	0.8 [0.8]	0 [0]	0 [0]	39.6 [56.2]
Katsina	31 [36.2]	0 [1]	0.1 [0.2]	6.8 [2.9]	0.2 [0]	0 [0]	62 [59.7]
Kebbi	44.2 [42.7]	0 [0]	1.5 [0.4]	1.7 [2.5]	0 [0]	0 [0]	52.6 [54.4]
Kogi	52.1 [39.5]	0 [1.7]	2.3 [4.5]	2.4 [5.2]	0.3 [1]	0 [0]	43 [48.1]
Kwara	54.9 [56.4]	0 [0]	1.5 [1.5]	4.7 [3.6]	0.5 [0]	0 [0]	38.3 [38.5]
Lagos	67.3 [57]	0.1 [0]	0.5 [0.9]	30.8 [40.9]	1.1 [0.9]	0 [0]	0.2 [0.3]
Nassarawa	27.7 [21.3]	0 [0.2]	2.2 [2.4]	6.2 [3.6]	0.4 [1.9]	0 [0]	63.6 [70.6]
Niger	42.5 [35.6]	0 [0]	0.3 [6.2]	1.4 [1.6]	0 [0]	0 [0]	55.9 [56.6]
Ogun	71.3 [69.8]	0.4 [0]	0.3 [0.8]	0.9 [8.5]	0.1 [0.3]	0 [0]	27.1 [20.4]
Ondo	58 [50.3]	0 [1.7]	4.3 [3.8]	3.4 [2.2]	5.3 [0]	0 [0]	29 [41.9]
Osun	67.6 [63.6]	1.6 [0]	0.3 [1.2]	0.5 [1.4]	0 [0]	0 [0]	29.9 [33.9]
Oyo	57.3 [47.5]	0.9 [0]	0.2 [5.3]	11.8 [8.2]	0 [0.2]	0 [0]	29.8 [38.8]
Plateau	23.8 [18.8]	2.4 [1.4]	3.3 [5.7]	3.8 [2.1]	1.1 [0.7]	0 [0]	65.6 [71.3]
Rivers	24.6 [41]	7.4 [0.7]	16.3 [13.8]	4.7 [11.9]	10.4 [10.9]	0 [0]	36.6 [21.7]
Sokoto	35.7 [29.8]	0.3 [0]	0.7 [0.2]	0.8 [0.3]	2.3 [0.2]	0 [0]	60.3 [69.5]
Taraba	3.7 [2.8]	0.7 [0]	2.4 [1.2]	1.7 [5.9]	0.3 [1.4]	0.1 [0]	91 [88.8]
Yobe	16.2 [18.1]	0.4 [0.7]	0.1 [0.7]	0.3 [2.1]	0.2 [0.4]	0 [0]	82.9 [78]
Zamfara	24.7 [21.5]	0 [0.2]	0.3 [0.2]	2.4 [0.5]	0 [0]	0 [0.5]	72.7 [77.1]
FCT	36.6 [38.3]	0 [0.3]	11.7 [10.6]	19.8 [23.7]	0.6 [0.2]	0 [0]	31.3 [26.9]
Average	47.3 [40.4]	1.1 [0.9]	2.7 [3.2]	5.8 [6.3]	1.6 [1.1]	0 [0]	41.4 [48]

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.

Table 9 presents the percentage distribution of households in Nigeria by type of fuel for cooking in 2007 and 2008. The table shows a greater portion of Nigerian households still depend on traditional fuels for cooking. About 74% of households in Nigeria depend on fire wood as cooking fuel in 2007, this further rose to over 79% in 2008. Households using kerosene decreased from 22.95 in 2007 to 18.55 in 2008. This may be attributed to high cost of kerosene in the market which made it unaffordable for many Nigerians. In both years, households using electricity and gas recorded the least with 0.7% each in 2007, 0.2% for electricity and 0.65% for gas in 2008. This is not surprising given that many Nigerians are poor and cannot afford the cost of gas for cooking while electricity supply is also erratic. Lagos State recorded the highest usage of kerosene in the years with 89.7% in 2007 and 91.1% in 2008, while Bauchi and Jigawa recorded the least with 1.6% each.

5. Potential for improving energy access and consumption through renewable energy

Achieving sustainable development through energy security while at the same time combat the challenges of global warming, is a target that is now widely recognised as crucial to global popular opinion. In this regard, the utilisation of renewable energy resources, such as solar, wind, hydro, biomass and geothermal energy, appears to be one of the most efficient and sustainable ways of achieving this target. Globally, there has been upward trend in the utilisation of renewable energy in the generation of modern energy (electricity). Table 10 presents the developments and share of renewable energy in electricity generation in some selected countries and world total for selected years.

Renewable, except hydro, have zero shares in power generation in Nigeria despite its abundant existence in the country. Meanwhile, economically-feasible renewable energy potential in Nigeria is projected to contribute 2036 MW, 6905 MW and 68,345 MW to electricity consumption profile in the country in the short, medium and long-term respectively [13]. Thus, pursuit and implementation of sustainability-based energy policy could provide more than 37% of Nigeria's total energy consumption in the long-run.

5.1. Renewable energy sources in Nigeria

5.1.1. Biomass

Biomass is energy derivable from sources of plant origin such as trees, grasses, agricultural crops and their derivatives, and animal wastes. As an energy source, biomass can be used as solid fuel, or converted to liquid or gaseous forms (biogas) through a variety of technologies for the generation of electric power, heat or fuel for motive power. Biomass resources available in the country include fuelwood, agricultural waste and crop residue, sawdust and wood shavings, animal dung/poultry droppings, and industrial effluents/municipal solid waste.

Over the years, fuelwood and charcoal have constituted between 32% and 40% of total primary energy consumption [14] largely dominated by households. As at 2008, about 80% of Nigerian households depend on firewood as cooking fuel. About 350,000 ha of forest and natural vegetation are lost annually due to various factors while

Table 9
Percentage distribution of households by type of fuel for cooking, 2007 and 2008.

State	Electricity	Gas	Kerosene	Wood	Coal	State	Electricity	Gas	Kerosene	Wood	Coal
Abia	0 [0.2]	0.7 [0.7]	25.8 [21.4]	73.6 [77.8]	0 [0]	Katsina	1.7 [0]	0 [0]	0.5 [2.2]	97.5 [97.8]	0.2 [0]
Adamawa	0.5 [0.2]	0 [0.4]	6.2 [2.3]	93.4 [96.8]	0 [0.4]	Kebbi	0.5 [0.2]	0.2 [0.4]	0 [4.8]	99.2 [94.6]	0.1 [0]
Akwa Ibom	0 [0]	0.2 [1.5]	18.3 [15.7]	81 [82.4]	0.4 [0.3]	Kogi	0.3 [1]	0 [0.3]	12 [18.9]	86.6 [79.6]	1 [0.2]
Anambra	0.4 [0]	0.3 [0.7]	26.8 [21.7]	72.2 [77.3]	0.3 [0.2]	Kwara	1.1 [0]	0 [0.2]	15.5 [12.7]	62 [74.3]	21.4 [12.7]
Bauchi	0 [0]	0 [0.2]	2.1 [1.6]	97.6 [98.2]	0.3 [0]	Lagos	2.8 [0]	3.8 [6.2]	89.7 [91.1]	3.1 [2.7]	0.6 [0]
Bayelsa	0.9 [0.8]	0 [0.4]	41.3 [47.5]	57.6 [51.4]	0.2 [0]	Nassarawa	0 [0.5]	0 [0]	9.2 [7.9]	90.8 [91.1]	0 [0.5]
Benue	0 [0.2]	0.4 [0]	3.1 [2.8]	94.5 [96.5]	2 [0.5]	Niger	0.7 [0]	0 [0.2]	5.2 [9.6]	92.9 [89.3]	1.2 [0.9]
Borno	0 [0]	0 [0]	1.3 [2.1]	98.4 [94.3]	0.3 [3.6]	Ogun	2 [0]	0 [0.7]	48.8 [60.9]	49 [37.3]	0.3 [1.2]
C/River	0 [0]	0.2 [0.2]	19.6 [13.6]	79.8 [86.3]	0.3 [0]	Ondo	0.2 [0.2]	0.2 [0.3]	32.6 [17]	66.7 [82.5]	0.3 [0]
Delta	0 [0.3]	1.6 [1.2]	21.3 [36.6]	76.6 [61.6]	0.5 [0.2]	Osun	0.8 [1.2]	0.2 [0]	27.1 [45.7]	56 [49.6]	15.9 [3.5]
Ebonyi	0.1 [0]	0.8 [0]	9.2 [6.9]	90 [93.1]	0 [0]	Oyo	0.1 [0]	1.3 [0.5]	44.7 [43.6]	50.2 [44.1]	3.8 [11.8]
Edo	2.1 [0.2]	0.1 [0]	18.6 [25.5]	78.7 [74.3]	0.5 [0]	Plateau	0.6 [0.2]	0.4 [1]	16.8 [10]	80.8 [88.8]	1.4 [0]
Ekiti	0 [0.7]	0 [0.3]	24.2 [36.6]	74.3 [61.5]	1.5 [0.9]	Rivers	0 [0.3]	2.8 [1.7]	31.3 [38.9]	65.2 [59.1]	0.7 [0]
Enugu	0.1 [0.2]	2.1 [0.7]	28.3 [21.3]	68.9 [77.3]	0.6 [0.5]	Sokoto	0.6 [0.2]	0.3 [0]	2.5 [6.3]	96.2 [93.5]	0.5 [0]
Gombe	2.1 [0.3]	0 [0]	5.5 [3.6]	92.4 [95.9]	0 [0.2]	Taraba	0 [0]	0 [0]	1 [2.6]	98.8 [97.4]	0.2 [0]
Imo	0.2 [0.5]	0.7 [1]	13.6 [7.4]	85.1 [90.9]	0.4 [0.3]	Yobe	0 [0]	0 [0]	0.9 [2.3]	98.7 [97.7]	0.4 [0]
Jigawa	1 [0.2]	0 [0.3]	3.9 [1.6]	95.1 [97.8]	0 [0.2]	Zamfara	0.1 [0]	0.1 [0]	4.1 [1.7]	95.5 [98.3]	0.3 [0]
Kaduna	0.3 [0.2]	1.2 [0]	9.8 [8.7]	88.5 [90.7]	0.2 [0.5]	FCT	0.7 [0.2]	3.4 [1.9]	34.5 [38.7]	57.4 [57.6]	4 [1.7]
Kano	1.3 [0.5]	0.1 [0.2]	3.4 [4.5]	94.9 [94.1]	0.3 [0.7]	AVERAGE	0.7 [0.2]	0.7 [0.6]	22.9 [18.5]	74.1 [79.6]	1.6 [1.1]

Source: NBS/CBN/NCC Social-Economic Survey on Nigeria, 2008.
Note: 2008 figure in parenthesis.

Table 10
Share of electricity generation from renewable sources for selected countries, 1990–2006.

	Years							
	1990		1995		2000		2006	
	Including hydro	Excluding hydro	Including hydro	Excluding hydro	Including hydro	Excluding hydro	Including hydro	Excluding hydro
Austria	66.2	2.3	70.5	3.3	72.3	2.8	67.6	8.4
Germany	3.7	0.6	5.1	1	6.3	2.5	12	8.7
Italy	16.4	1.6	17.5	1.6	18.9	2.5	18	5.4
Portugal	34.7	2.5	28.3	3.2	30.3	4.2	34	10.4
Spain	17.2	0.4	14.9	0.9	16.3	3	18.7	9.6
United Kingdom	1.8	0.2	2.1	0.6	2.6	1.3	5	4.1
Turkey	40.4	0.1	41.6	0.4	24.9	0.2	26.3	0.2
Nigeria	35.7	0	39.23	0	40.3	0	34.7	0
World	17.4	1.7	17.2	1.7	15.8	1.9	18.9	2.3

Data source [12].

Table 11
Biomass resources and the estimated quantities in Nigeria.

Resource	Quantity (million tonnes)	Energy value ('000 MJ)
Fuelwood	39.1	531.0
Agro-waste	11.244	147.7
Sawdust	1.8	31.433
Municipal solid waste	4.075	–

Sambo [16].

the national demand is projected to increase to 91 million tonnes by 2030 [15]. This has great implications on sustainable environment, food security and health of the low income households who depend largely on woodfuels. The strategic ways of controlling this problem is a dual approach of reducing consumption rate through promotion of more efficient wood stoves and deployment of alternatives to fuelwood through policy instrument and development of renewable energy technology. Specifically, the government needs to address the problems posed by deforestation by making use of these resources efficiently through improved renewable energy technologies, thereby reduces the direct use of traditional biomass (fuelwood, crop residue, municipal wastes, sawdust, etc.) and improves modern energy access. Table 11 presents the biomass energy potential in Nigeria.

5.1.2. Solar

Nigeria lies within a high sunshine belt and has abundant solar potentials that can be converted into electricity for its populace. The annual average of total solar radiation varies from about 3.5 kWh m^{-2} day^{-1} in the coast to about 7 kWh m^{-2} day^{-1} along the semi-arid areas in the far North. On the average, the country receives solar radiation at the level of about 19.8 MJ m^{-2} day^{-1}. Average sunshine hours are estimated at 6 h day^{-1}. The minimum average is about 3.55 kWh m^{-2} day^{-1} in Katsina in January and 3.4 kWh $m^{-2}day^{-1}$ for Calabar in August and the maximum average of 8.0 kWh $m^{-2}day^{-1}$ is recorded for Nguru in May. Given an average solar radiation level of about 5.5 kWh$m^{-2}day^{-1}$, and the prevailing efficiencies of commercial solar-electric generators, then if solar collectors or modules were used to cover 1% of Nigeria's land area of 923,773 km^2, it is possible to generate 190,550 (1850 $\times$ 103) GWh of solar electricity per year. This is over one hundred times the current grid electricity consumption level in the country. In spite of this significant potential and the proper conditions for solar energy application in the country, the present contribution of solar energy to the total energy generation is still very negligible. Photovoltaic (PV) power generation in Nigeria is still at a pilot stage.

5.1.3. Wind

Wind energy is the fastest growing energy source globally and wind power is one of the most widely used alternative sources of energy today. It produces a clean form of energy and is a renewable source of electricity [17]. With country's location at 10° N of the equator, Nigeria's location is favourable for wind power generation. Wind is available at annual average speeds of about 2.0 m/s at the coast latitudes and 4.0 m/s at the far northern part of the country. At air density of 1.1 kg/m^3, wind energy intensity, perpendicular to the wind direction, ranges from 4.4 W/m^2 at the coasts to 35.2 W/m^2 at the northern extreme. Harnessing this resource can greatly increase energy generation and significantly improve energy access and consumption in the country. However, this energy source has not been significantly harnessed and its utilisation has been limited to pilot projects mostly concentrated in some of the northern states of the country.

Table 12
Hydropower potential and utilisation in selected African countries (in GWh/yr).

Country	Gross theoretical hydropower	Technically feasible hydropower	Economically feasible hydro	Installed hydro capacity (MW)	Production from hydro plants	Percentage of electricity produced from hydro	Hydro capacity under construction (MW)	Planned hydro capacity (MW)
Algeria	12,000			280	500	2		700 (p-s)
Angola	150,000	90,000	65,000	290	1000	56	780	<16,500
Cameroon	294,000	115,000	103,000	725	2423	99		600
Congo		>50,000		89	352	>90		180
Congo DR	1,397,000	774,000	<419,210	2400	5350	99	4	43,000
Cote d' Voire	46,000	>12,400	12,400	614	1800	60		334
Egypt		>50,000	50,000	2810	11,450	20	65	193
Ethiopia	650,000		260,000	398	1600	97	297	705
Ghana		10,600		1072	5169	71		400
Madagascar	321,000	180,000	49,000	105	510	72	42	350
Morocco		4700	4000	1205	2350	18	90	450 (p-s)
Mozambique	50,000	37,647	31,717	2180	11,548	94		2000
Nigeria	42,750	32,450	29,800	1938	6986	43	64	4850
South Africa		na		668	904	0		na
Tanzania	39,447	20,000	1789	377	1748	85	180	>1000
Zambia	52,460	28,753	11,000	1674	7782	100	60	>2000
Zimbabwe	18,500	17,500		670	3000	25	85	>800

Source: World Atlas on hydropower and dams [19].
Notes: na – data not available but greater than zero; p-s: pump storage.

5.1.4. Hydro

Nigeria is ranked ninth in hydropower potential in Africa with technically and economically feasible hydro power energy at 32450 GWh/yr and 29,800 GWh (Table 12) respectively. Similar to other African countries however, the country only used about 21.5% (6986 GWh/year) of her potential for the year 2001. According to ECN [18], Nigeria has a gross exploitable large hydro potential of 14,750 MW out of which only 14% (1930 MW) is harnessed, contributing approximately 30% of total installed grid connected electricity generation. Hydro electricity generation in the country is largely dominated by large hydropower with little or no contribution from small hydropower despite the country's significant potentials. Small hydropower (SHP) plants have been in existence in Nigeria since 1923, about 45 years prior the commissioning of the country's first large hydropower – Kainji. Today, SHP technology is yet to be significantly developed with the schemes operating in only three states of the Federation – Plateau, Sokoto and Kano – with a nameplate capacity of just 30 MW [18]. Unlike in developed countries where SHP plants have been widely adopted in electricity generation and other applications, little attention is paid to its significance in spite of the vast potential, and high and increasing energy needs in Nigeria.

6. Conclusion and policy recommendations

This study has examined the access to electricity and pattern of energy consumption among the Nigerian households. The study found that despite the importance of energy to economic performance, greater proportion of Nigerian households do not still have access to electricity while many of those that have access have also resulted to the use of diesel generating sets as supplements due to constant power outage. For instance, only about 40% of the total households had access to the national grid while more than 45% do not have access to any form of electricity. Moreover, more than 6% of households have supported their access to the grid with self diesel generator while more than 3% have completely relied on self generator possibly to save themselves from the psychological cost associated with intermittent electricity supply (i.e., constant blackout) in the country. It was also found that with just 1.1% of households having access, the rural electrification programme is yet to make a significant contribution to electricity supply/access in the country. In another development, examination of energy consumption pattern reveals that more than three-quarters of Nigerians still depend on firewood as their cooking fuel while about 20% rely on kerosene. This is not surprising given the low access to the modern form of energy (electricity) and low reliability of electricity services in Nigeria. Thus, this shows the urgent need for the government efforts for further developments of the overall Nigerian electricity sector and to intensify efforts in order to improve the rural electrification programme to ensure rapid economic development. This can be greatly achieved by significantly harnessing the renewable energy resources in the country.

Except for large scale hydropower which serves as a renewable source of electricity, the current status of renewable energy resources' exploitation and utilisation in Nigeria is very low, limited largely to pilot and demonstration projects. The main constraints in the rapid development and diffusion of technologies for the exploitation and utilisation of these enormous resources in the country include non-existence of market and the lack of appropriate policy, regulatory and institutional framework to stimulate demand and attract investors. The comparative low quality of the systems developed and the high initial upfront cost also constitute barriers to the development of markets [20]. Therefore, for the country to unleash this vast potential of its renewable energy resources on its drive to meet its energy needs and achieve the millennium development goals (MDG) and Vision 2020, these barriers must be eliminated through significant investment in critical areas of R&D, building of indigenous human and physical capacities and the intensification of the on-going economic reform to create an investor friendly environment to attract renewable energy investment from private investors.

The current renewable energy situation of the country indicates that a significantly higher level of utilisation could be attained when properly exploited and managed. However, the existing technology status shows that Nigeria is in dare needs of technical assistance from pro-active countries especially from the industrialising developing nations and multilateral institutions in advancing renewable energy technologies in the country for rapid transformation of its renewable resources. Some of the technical assistance includes the acquisition of a manufacturing plant for small hydro turbines' components, biogas technology for the development of biogas for cooking and electricity generation, widespread renewable energy data recording stations, and wind turbines and generators technology, among others.

Finally, for sustainability of the system, government at all levels must be strongly committed to the development of renewable energy utilisation and the progress has to be continuously reviewed to know how well it performs. Proper monitoring of the system has to be put in place for proper policy formulation at all time.

References

[1] Steer A, Stern R, Bond J, Watson R, Georgieva K, Raczynski A. Fuel for thought––an environmental strategy for the energy sector. The World Bank; 2000.

[2] Hydropower resource assessment of Africa. Ministerial conference on water for agriculture and energy in Africa: the challenges of climate change; 2008. Available at http://www.sirtewaterandenergy.org/docs/2009/Sirte 2008 BAK 3.pdf (accessed 12.07.2010).

[3] Sambo AS, Iloeje OC, Ojosu JO, Olayande JS, Yusuf AO. Nigeria's experience on the application of IAEA's energy model (MAED & WASP) for National Energy Planning. Republic of Korea: Korea Atomic Energy Research Institute; 2006. Available at http://www.energy.gov.ng/index.php?option=com docman& task=cat view&gid=21&dir=DESC&order=name&limit=5&limitstart=5 (accessed 08.04.2010 at 13:53).

[4] Kucukali S, Baris K. Assessment of small hydropower (SHP) development in Turkey. Energy Policy 2009;37:3872–9.

[5] Aigbokan BE. Evaluating investment on basic infrastructure in Nigeria. In: Proceedings of the eighth annual conference of the Zonal Research Units Organised by Research Dept., Central Bank of Nigeria. 1999. p. 208.

[6] The World Bank, World Development Indicators, 2010 and National Population Commission, Abuja 2010.

[7] Federal Government of Nigeria (FGN), Report of the Vision 2020 National Technical Working Group on Energy Sector, Abuja July, 2009.

[8] International Energy Agency (IEA), World Energy Balances of Countries, (2010 edition). Available at www.iea.gov, (accessed on 12:01:2011at 17:30).

[9] International Monetary Fund (IMF), African Development Indicators; 2009.

[10] Central Bank of Nigeria (CBN), Statistical Bulletin, Abuja; 2008.

[11] Sambo AS. The challenges of sustainable energy development in Nigeria. In: Paper presented to the Nigerian Society of Engineers Forum, 2nd April. 2009.

[12] Energy Information Administration (EIA), World Net Electricity Generation by fuel Sources; 2007.

[13] Sambo AS. Alternative generation and renewable energy. In: Paper presented at the 2nd Power Business Leaders Summit. 2007.

[14] Report of the Inter-Ministerial Committee on Combating Deforestation and Desertification; August 2000.

[15] The Presidency, Report on the National Fuelwood Substitution Programme; 1992.

[16] Sambo, AS. Strategic Developments in Renewable Energy in Nigeria, International Association for Energy Economics. Third Quarter 2009, p. 15–9.

[17] Ogulata RT. Energy sector and wind energy potential in Turkey. Renewable and Sustainable Energy Reviews 2003;7:469–84.

[18] Energy Commission of Nigeria (ECN). Renewable Energy Master Plan (REMP), Abuja; 2005.

[19] Kalitsi EAK. Problems and prospects for hydropower development in Africa. In: The Workshop for African Energy Experts on Operationalizing the NGPAD Energy Initiative. 2003. Available from: http://www.un.org/esa/sustdev/sdissues/energy/op/nepadkalitsi.pdf (accessed 17.08.11).

[20] Sambo AS. Matching electricity supply with demand in Nigeria. Fourth Quarter: International Association for Energy Economics; 2008.